RUNNING HEAD: Diadochokinesis in HFA

Comparing Motor Speech Skills of Children with High Functioning Autism versus those of Typically Developing Children using Diadochokinetic Tasks

Honors Research Thesis

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ABSTRACT

Motor speech function assessments have long been used to help determine diagnoses and treatments for speech-language pathology clients that are suspected of having apraxia, dysarthria, or other frank motor speech disorders. However, motor speech function is rarely assessed in children who may show more subtle motor speech problems, such as speech clients with autism spectrum disorders (ASDs), developmental disorders that primarily affect the development of social and communication skills. The purpose of this study is to look at the particular speech motor task of diadochokinesis (DDK) and determine whether there are group or stimulus type effects on performance. Specifically, (1) are there differences between children with high functioning autism (HFA) and typically developing (TD) children on DDK measurements (rate, accuracy, and consistency)?, and (2) do participant groups differ in their performance on monosyllabic versus multisyllabic stimuli?. To perform this study, two groups (HFA and TD children) were given the DDK task of repeating monosyllabic sounds (/pa/, /ta/, and /ka/) and then multisyllabic sounds (/pataka/) as long and as fast as they could. Mean performances from both groups were compared on the measurements of rate, accuracy, and consistency. The results showed that the HFA group performed generally faster rates across the tasks, but had significantly lower accuracy and consistency scores than the TD group. The findings also showed that, in terms of rate, all participants performed more poorly on the multisyllabic task than the monosyllabic tasks, regardless of group membership. Although the number of participants was small, this study showed promising results in using the DDK task to assess the motor speech skills in children with autism. Further studies are suggested for looking at the importance of rate, accuracy, and consistency in the utterances of HFA children.

INTRODUCTION & BACKGROUND

Introduction to Motor Speech Function Assessment

Assessment of motor speech function can be an important element in the accurate diagnosis and treatment of pediatric speech-language pathology clients. However, assessments of motor speech function are usually performed only on clients suspected of having frank motor speech disorders (e.g. those that occur in association with neurologic conditions such as cerebral palsy, or after a neurologic insult, such as a stroke). For example, motor speech function is frequently assessed in children with pediatric motor speech disorders. Such disorders fall into the major categories of childhood apraxia of speech (CAS), a disorder associated with difficulties in the planning of movements needed for speech (e.g., lips, jaw, or tongue), and dysarthria, a speech disorder associated with difficulties in execution of articulatory movements. In contrast, motor speech function is rarely assessed and little work has been done in examining motor speech skills in children who may show more subtle motor speech problems, such as clients with autism spectrum disorders (ASDs), developmental disorders that primarily affect the development of social and communication skills. Because most of the communication problems in children with autism appear to be language-based, more focus has been put on social communication and language assessments than on assessments in other areas. The purpose of this study, therefore, is to begin to consider the nature of motor skills in this population.

Motor Speech Performance in Children with Autism

Evidence exists that children with high functioning autism (HFA) sometimes show differences in communication that include subtle differences in motor speech performance. According to Shriberg, Paul, and McSweeny (2001), when compared to typically developing speakers, more HFA clients "had residual articulation distortion errors, uncodable utterances due to discourse constraints, and utterances coded as inappropriate in the domains of phrasing, stress, and resonance" (p. 1097). The biggest differences between HFA and typically developing speakers in the study by Shriberg et al. were in articulatory precision and prosody. In fact, these differences are so distinct that "the prosody characteristics of a person with autism constitute one of the most significant obstacles to his or her social integration" (Shriberg et. al, 2001, p. 1099). Shriberg et al. (2001) also estimated that the prevalence of HFA speakers with distortion errors is 33%, as compared to the typical adult population with 1-2% errors (p. 1109). The high prevalence of residual articulation errors found in the HFA population, according to these researchers, argues for the need for the study of speech testing of younger HFA speakers. With earlier screening of speech motor problems in the HFA population, earlier and more effective therapy can become available for these clients.

Diadochokinesis as a Measure for Motor Speech Performance

This study compares the performance of children with high functioning autism (HFA) with that of children who are neurotypically developing on one frequently used motor speech task: diadochokinesis (DDK). This task is used to test an individual's ability to repeat a syllable or a syllable sequence as quickly as possible in order to look at motor speech skills separate from the effects related to word familiarity. DDK analysis includes a comprehensive look at the speed, accuracy, and consistency of an individual's productions for either monosyllabic (/pa/, /ta/, or /ka/) or multisyllabic (/pataka/) sequences. The rate of a speaker's productions is the most common measure of DDK performance. Not only is rate the easiest oro-motor skill to measure, but it has also been described as the simplest way to recognize motor speech difficulties in a child (Williams & Stackhouse, 2000). However, accuracy of speech movements is also an important measure in terms of intelligibility of speech, vocabulary skills, and spelling skills

(Stackhouse, 1996). Finally, although consistency is the most difficult skill to measure, it has also been described as the speech motor skill that may most clearly differentiate categories of speech problems (Williams & Stackhouse, 2000). Together, rate, accuracy, and consistency can be used to compare children's productions to an adult model and also with their own speech skills. Therefore, the main questions examined in this study are as follows: (1) Are there differences between HFA and typical children on DDK measurements (rate, accuracy, and consistency)?, and (2) Are results similar for monosyllabic and multisyllabic stimuli for both participant groups?

The difference in performances of monosyllabic word and multisyllabic word stimuli is interesting to look at because of the planning component of multisyllabic vs. monosyllabic words and the diagnostic differences associated with these stimuli. Children with very slow repetition rates for both monosyllables and trisyllabic sequences have been classified as dysarthric, while children with slower trisyllabic sequences than monosyllablic rates have been classified as having Childhood Apraxia of Speech (CAS). However, how would children with HFA perform on monosyllabic vs. trisyllabic MRR? Diadochokinesis represents a widely used clinical approach to looking at these questions, which may help characterize the nature of motor differences seen in children with HFA.

Background

The diadochokinetic (DDK) performance task is a motor speech task used to test a client's ability to repeat a syllable or a syllable sequence at a maximum rate, or as quickly as possible (Kent, Kent, & Rosenbek, 1987). It is intended to determine how rapidly an individual can start and stop the movement of articulators and how accurately and consistently a client can "execute repetitive, alternating, sequential movements typically associated with speech articulation" (Johnson, 1980). In short, this task is used to assess speech motor coordination and control of articulation (Thoonen Maassen, Wit, Gabreels, & Schreuder, 1996). DDK, also known as Maximum Repetition Rate (MRR), can be measured in two different ways. DDK can be determined by counting the specific number of syllables produced in a given time interval, or by recording the amount of time in which a certain number of syllables are produced. The latter, known as time-by-count measurement, is considered easier to administer and is more commonly used (Fletcher, 1972). To score DDK performance, the examiner looks at rate, accuracy, and consistency. Rate is the measure of number of repetitions per time taken, accuracy is the number of correct repetitions per total amount of repetitions, and consistency is the number of repetitions that match the first attempt per the total amount of repetitions (Fletcher, 1972).

The DDK stimuli that are most frequently used and for which there are the largest amount of normative data are the monosyllables [pa], [ta], and [ka], and the polysyllabic sequences [pataka], "buttercup," or "pattycake" (Kent, Kent, & Rosenbek, 1987). To elicit a monosyllabic sequence, the examiner models a syllable (e.g., "/pa/, /pa/, /pa/") as quickly and clearly as possible, then has the examinee repeat the syllables back for a designated amount of time. The polysyllabic sequence administration follows the same guidelines by having the child repeat back the sequence (e.g., "/pataka/") as quickly as possible (St. Louis & Ruscello, 2000). It is important to look at both monosyllabic and multisyllabic stimuli because they yield such different results. Children with speech difficulties have been found to perform differently for a repetition of the same sound versus the repetition of a different sound (Thoonen, Maassen, Gabreels, & Schreuder, 1999). Kent, Kent, and Rosenbek (1987) created a table (reproduced in Table 1) that compared MRR data in syllables per second for various syllable sequences, with data from Fletcher's (1972) time-by-count values. For children ages 6 through 14 years old, monosyllabic sequences were produced the most rapidly at 3.6 to 6.1 syllables per second. Disyllabic sequences took longer to produce, at 1.9 to 3.6 syllables per second. The trisyllabic sequence of [pataka] took the most time to produce, at 1.0 to 1.8 syllables per second. This information demonstrates the extra time required to plan and produce multisyllabic sequences versus monosyllabic repetitions.

DDK data have been used in multiple ways. The main purpose of DDK tasks is to identify speech motor function issues that may contribute to a speech sound disorder in a child (Rvachew, Ohberg, & Savage, 2006). In addition, DDK rate has "been shown to provide a sensitive indicator of the presence and severity of neurological impairment and evolution of changes over time in both developmental and acquired disorders" (Gadesmann & Miller, 2008). Finally, combined quantitative and qualitative measures related to DDK have supported differential diagnoses for classification of neuromuscular dysfunction and speech subsystem problems (Gadesmann & Miller, 2008). Overall, this information helps with identifying causes of motor speech impairments, which ultimately may assist in treatment planning.

As indicated previously, DDK data is especially useful in assisting with the identification of the two main pediatric motor speech disorders: apraxia of speech and dysarthria. Rvachew, Ohberg, and Savage (2006) used the maximal performance tasks of prolongation and DDK to see the possible benefits for identifying apraxia of speech and dysarthria in a group of 20 children. The responses to the prolongation task were highly variable among all the children, making it a poor indicator of dysarthria or apraxia of speech, according to the authors. However, the repetition rates were stable among the children: the monosyllable and trisyllable repetition rates were at least 3.4 syllables per second for all but one child. This makes the DDK task a reliable tool for finding delays or differences in repetition rate. Using the repetition rate as the basis of diagnosis and classification, Thoonen et al. (1999) used scores of 0, 1, and 2 to classify both dysarthria and CAS, with 0 being not dysarthric/dyspraxic and 2 being dysarthric/dyspraxic. Children with monosyllabic MRR <3.0 syllables/second were considered dysarthric (score of 2) and children with trisyllabic MRR <3.4 syllables/second (or were unable to produce a correct sequence) were considered dyspraxic (score of 2). This study suggested that spastic dysarthria can be diagnosed based on MRR composite scores and that difficulties in sequencing speech movements is a significant diagnostic sign of CAS. Overall, diagnostic differentiation can be objectified and quantified through maximum performance tasks such as DDK (Thoonen, Maassen, Gabreels, & Schreuder, 1999).

Accuracy is another important measure of DDK performance to observe. In general, studies involving typically developing children showed that accuracy in DDK tasks increased as age increased (Fletcher, 1972, and Williams & Stackhouse, 2000). This suggests that this aspect of DDK is a sensitive measure that can be helpful in determining children who are not developing typically in motor speech skills, at least for some age groups. However, the less developed speech and vocabulary skills of very young children need to be taken into account in order to avoid the misdiagnosis of oral-motor speech difficulty in a child whose development is comparable to peers.

Finally, consistency measures are also very developmentally sensitive in DDK assessments. In a study by Williams and Stackhouse (2000), researchers found that consistency improved greatly from a group of 3-year-olds to a group of 4-year olds. Many of the typically developing children in the 3-year-old had at least one inconsistent response involving minor motor speech movements, but such inconsistencies decreased with age. Often, children in the 3-year-old group were consistent even if they were inaccurate; however by age 4, most children were giving both accurate and consistent responses. This observation is a useful finding for clinical practice, because it can suggest the nature of a child's speech disorder. According to Williams and Stackhouse (2000), "Children with delayed speech development who use simplifying phonological processes may substitute sounds, but in a consistent way (e.g. fronting, stopping, cluster reduction). Other children who have motor programming and/or auditory processing difficulties may be more inconsistent in their responses" (p. 287). Therefore, inconsistency in DDK tasks may assist in diagnosing more inclusive speech processing problems.

Although the DDK task has been widely used as part of the diagnostic battery for speech disorders, some problems with its use have been identified. For example, Cohen, Waters, and Hewlett (1998) summarized five common problems seen in the collection and analysis of DDK data from children. The main problems the identified in the use of DDK procedures were limited amounts of normative data, problems with eliciting the data, types of data (i.e., words vs. non-words), and especially differences in analysis procedures. The three main analysis issues were timing a subject's performance, calculating DDK rate from the data, and dealing with errors in pronunciation of the target sequence. Because of these various issues, highly variable findings have been obtained for DDK rate across studies. According to Cohen et al (1998), an engaging and useful procedure for data collection and analysis protocol is lacking. This can be extremely detrimental when looking at motor speech skills in children with HFA. A purely objective assessment that only focuses on motor speech ability is necessary for this population so that the examiner can isolate the cause for speech difficulties.

New methods have been proposed that may compensate for some of the challenges in using DDK that were mentioned above. For one, there are different testing methods (Rvachew, Hodge, & Ohberg, 2005; Rvachew, Ohberg, & Savage, 2006). Rvachew, Hodge, and Ohberg (2005) digitally recorded MRR sound files and measured them by looking at the time it took each subject to repeat the same syllable 10 times in one breath. The experimenters also looked at trisyllables. Then, they calculated how many syllables were uttered per second. In combination with the differential diagnosis flowchart developed by Thoonen et al. (1999), Rvachew et al. established different diagnoses for dysarthria and dyspraxia. As an additional step, Shriberg and Paul have suggested that researchers no longer just look at the DDK rate, but that they also look at deletions, substitutions, and distortions of sounds to help classify motor speech disorders (Shriberg & Paul, 2011). This demonstrates that the DDK task, when only including rate, accuracy, and consistency, may not fully measure the effectiveness of subjects' motor speech abilities.

Technology has also improved. For example, Westbury and Dembowski (1993) used an x-ray microbeam system to measure performance, which used pellet constellations attached to the tongue associated with acoustic signals. These pellets were used to measure posture, drift, range of motion, mean pellet speed, and skewness. In a typical diadochokinetic record, the researchers found some pellet positions oscillated in time with an acoustic wave. The results of the pellet movements showed that speakers tended to adopt strategies when performing diadochokinetic tasks. Although these methods have not been adopted more widely, they are of interest because they may help to explain some of the individual differences of utterances within a group.

Finally, additional normative data have been obtained. Williams and Stackhouse (2000) looked at the rate, accuracy, and consistency of the performance of 30 typically developing children on DDK tasks. The goal was to collect normative data so that future examiners might understand the nature of children's speech difficulties, interpret the data from DDK results, and come up with appropriate therapy based on the results. Williams and Stackhouse found that DDK tasks can provide a wealth of information about children's speech skills if the performances are analyzed correctly, but overall consistency and accuracy were the most sensitive measures to examine when questions of motor speech skill are being addressed.

Speech differences in children with HFA

The study by Shriberg et al. (2001) showed that individuals with HFA display a range of speech difficulties, including articulation distortion errors, uncodable utterances, and phrasing, stress, and resonance issues. Articulatory precision and prosody were the most distinguishable features between HFA children and typically developing children. The high prevalence of residual articulation errors found in the HFA population demonstrates the need for the study of speech testing of younger HFA speakers as a means of screening speech motor problems in order to facilitate in earlier and more effective therapy options for these clients. Currently, however, there is a lack of data examining the feasibility and value of DDK for assessing the HFA population. These children would need to be compared to children with typical development in order to determine the extent of similarities and differences. Differences in vulnerability of the DDK task must also be evaluated to see if the reliability is comparable for different disorders.

The goal of the present study is to compare the performance of children with high functioning autism (HFA) with those of children who are neurotypically developing on the motor speech task of diadochokinesis. This study includes the assessment of rate, accuracy, and consistency differences for two types of stimuli, monosyllabic repetitions and trisyllabic repetitions, as well as the relative performances on the monosyllabic versus trisyllabic stimuli compared to those of typically developing children. The two primary questions are as follows:

(1) Are there differences in performance on DDK tasks between typically-developing children and children with autism?, and (2) What are the differences in performance for monosyllabic sequences vs. trisyllabic sequences?

METHODS

Design

The study uses a DDK task to examine speech motor characteristics in children with High Functioning Autism (HFA) versus those in children with Typical Development (TD). The design is mixed analysis of variance and will involve the study of the following dependent variables among the: rate, accuracy, and consistency of targeted speech productions. Independent variables are group (HFA/TD) and task (monosyllabic versus trisyllabic). The data are coming from a larger study with IRB approval ("Motor speech characteristics of children with and without autism," Protocol number: 2010B0274), being conducted by Ph.D. student Richa Deshmukh, with Professor Rebecca McCauley as the Principal Investigator. The results of this analysis will be useful in differentiating between the speech motor characteristics in the HFA and those in the TD groups.

Participants

The dissertation project that serves as the parent study for the present one included plans for a total of 80 participants between the ages of 4 and 10 years old. To date, 12 children have been recruited who have been diagnosed with HFA and 8 with TD. For this study, 7 HFA and 7 TD participants were assessed and compared. Other groups associated with the larger, parent study included children with speech sound disorders (SSD group) and children with motor speech disorders (MSD group), but those groups will not be examined in this study. Participants were recruited through announcements in local schools, day care and medical centers, the OSU

Speech and Hearing Clinic, local hospitals, the Autism diagnostic clinic at the University's Nisonger Center, Nationwide Children's Hospital, and local speech and language clinics. Children were also recruited through a regional chapter of the Childhood Apraxia of Speech Association of North America (CASANA).

All children participating in the study met the following criteria, according to parental report:

1. absence of hearing impairment or physical disability
2. no history of head injury
3. reported oral expressive vocabulary of at least 20 words
4. ability to imitate at least 5 communicative gestures
5. receptive vocabulary within normal limits
6. current chronological age (CA) between 4 and 10 years
7. English as the primary language spoken at home

Test information regarding receptive and expressive vocabulary was obtained using the Peabody Picture Vocabulary Test-IV (PPVT-IV; Dunn, & Dunn, 2006) and the Expressive Vocabulary Test (EVT-2; Williams, 1997), respectively. These test data were supplemented by the parental report. Additional selection criteria for the HFA group included having receptive language within normal limits, meeting the autism cut-off score on Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003), and having a diagnosis of autism before the age of 3 years. The TD participants were required to have no previous diagnosis of a developmental disorder.

To describe the speech production skills of all participants, the Goldman Fristoe Test of Articulation-2 (GFTA-2; Goldman & Fristoe, 2000) was administered. To assess the consistency of productions beyond the context of DDK tasks, the participants were given the Diagnostic

Evaluation of Articulation and Phonology (DEAP; Dodd, Hua, Crosbie, Holm, & Ozanne, 2002). Finally, to confirm a physically normal oral mechanism, participants were administered the Oral Speech Mechanism Screening Examination, Third Edition (OSMSE-3; St. Louis & Ruscello, 2000).

The results of the preliminary screenings and assessments are found in Table 2. Between the groups, there are three main disparities: gender, average age, and SCQ results. As seen above, all participants in the HFA group were male, while only three of the seven participants in the TD group were male. Although a gender-balanced population is desirable for this type of study, it is part of the nature of the disorder that the HFA group is more heavily male. In fact, boys are four times more likely to be diagnosed with autism than girls (Kogan, Blumberg, Schieve, Boyle, Perrin, Ghandour, et al., 2009). However, gender differences have not been found to be a significant factor of DDK performance (Maturo, Hill, Bunting, Ballif, Maurer, & Hartnick, 2011). Another discrepancy is the age difference between the groups. The average age of the HFA group was 7 years, 4 months, while the average age of the TD group was 6 years, 10 months. Age was not found to be statistically significant through an independent samples t-test ($p = .633$). However, this six-month gap is still notable since age has been shown to be positively correlated with DDK performance (Williams & Stackhouse, 2000). Finally, SCQ results were dissimilar between the HFA and TD groups. A score of 15 or above on the SCQ measure indicates that a child may be identified as belonging on the autism spectrum. However, this test is a brief screening questionnaire and not a full diagnostic test, which may explain why two participants in the HFA group fall below this cut-off score. Other measures that were used to select participants for the HFA group included parent reports of qualification for school services and official autism diagnoses.

Procedure

The assessment began with the administration of the SCQ to the parents/caregivers of all participants to place them in a specific group: HFA or TD. Next, an experimenter individually administered a speech motor examination to each child. Although this examination included four tasks, the data from only one task (DDK) was used in the current study. The three other tasks were conversation, multisyllabic word repetition, and nonsense word repletion. The diadochokinetic task was performed second in the series of tasks and was used to determine each child's ability to produce syllabic sequences at a maximum rate. These sequences included /pa/, /ta/, /ka/, and /pataka/ (Strand & McCauley, 1999). Participants were asked to:

1. Say /pa/ (5) times slowly, naturally, and as fast as they can.
2. Say /ta/ (5) times slowly, naturally, and as fast as they can.
3. Say /ka/ (5) times slowly, naturally, and as fast as they can.
4. Say /pa, ta, ka/ (5) times slowly, naturally, and as fast as they can.

In many speech motor assessments, the monosyllabic task (repetition of /pa/, /ta/, or /ka/) is often used to differentiate between children with dysarthria and children with childhood apraxia of speech (CAS), while the trisyllabic task (repetition of /pataka/) is used to differentiate between children with CAS and TD children (Rvachew, Ohberg, & Savage, 2006).

The three other tasks in the speech motor examination were performed as follows:

1. Conversation: this initial assessment included a five-minute dialog sample was collected by having each participant describe his or her last birthday party and summer vacation.
2. Multisyllabic word repetition: the screening test of the Hodson Assessment of Phonological Patterns (HAPP-3; Hodson, 2004), which consists of multisyllabic words, was administered to each child. This task followed the DDK assessment.

3. Nonsense word repetition: the participants were asked to repeat 16 nonsense words from the Nonword Repetition Task (NRT) and 18 sounds from the Syllable Repetition Task (SRT). This was the final task of the speech motor examination.

The participants were then administered all assessments described in the materials, which included the OSMSE-3, DEAP, PPVT, EVT, and GFTA-2. This order was maintained for all participants in every group. The entire assessment window took approximately two hours.

Coding

The DDK responses were digitally recorded, listened to, and coded for rate, accuracy, and consistency as separate factors. The values for each child's production of a single DDK attempt was obtained using the methods from Williams and Stackhouse (2000, p. 276), as described below:

1. Rate: mean time was calculated by counting the number of repetitions uttered and dividing that by the amount of time taken for these attempts. For example, if the child repeated "pa" 20 times and it took 2.1 seconds to perform that attempt, the rate for that attempt would be 20 divided by 2.1, to yield a rate of 9.524 repetitions per second.
2. Accuracy: measured by dividing the number of correct repetitions by the number of total repetitions to find the percentage of accurate responses. Utterances that were phonetically comparable to the adult model were considered correct. Five correct repetitions of the target were scored correct. Fewer than five correct repetitions were scored incorrect. For example, if a child was attempting to repeat "pa" in a sequence, and uttered "pa" 14 times and "ta" 6 times, the accuracy for that attempt would be 14 divided by 20, to yield an accuracy score of 70%.

3. Consistency: measured by dividing the number of consistent repetitions by the number of total repetitions to find the percentage of consistent responses. In this study, the initial imitated response was considered the baseline, whether accurate or not. If the following responses matched the baseline response, they were scored as consistent. For example, if a child's target sound was "ta" but the first sound he uttered was "ka," the number of times he said "ka" in a sequence would be counted as consistent. If this child produced "ka" 5 times out of 20 utterances total, his consistency would be 5 divided by 20, to yield a consistency score of 25%.

The results of the coding were entered into a Microsoft Excel document for efficient comparison between the dependent variables.

Statistical Analysis

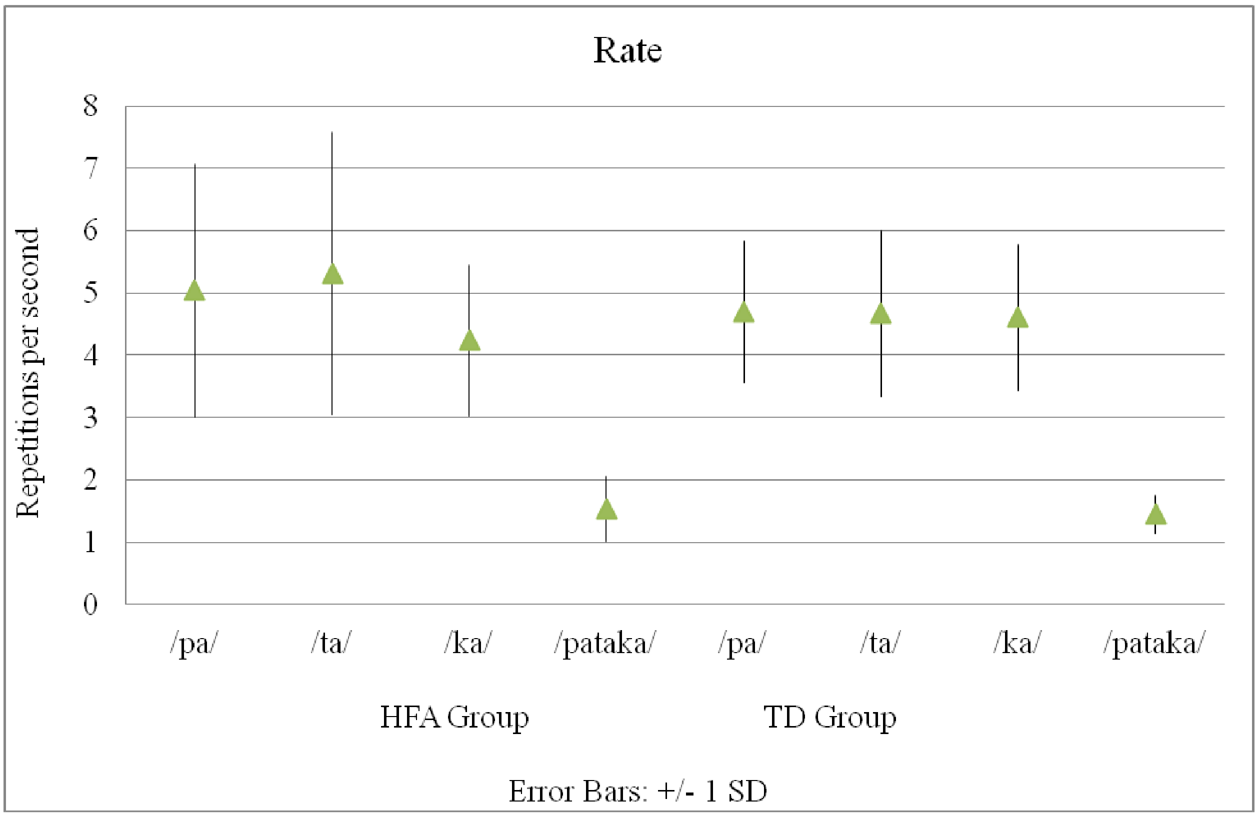
The primary goal of this study was to observe differences in speech motor characteristics in children with HFA and TD children. To examine these differences, a two-way ANOVA was used for each of the 3 dependent variables: rate, accuracy, and consistency. The independent variables consisted of Group (HFA vs. TD) and Stimulus Type (/pa/, /ta/, /ka/, and /pataka/). The two-way ANOVA tests for differences both between-subject (Group) and within-subject (Stimulus Type) factors. Therefore, there were a total of 3 analyses, one for each of the dependent variables. For the dependent variable of rate, the fastest rate of the 5 times that a child performed the task was used for data analysis. This was done to avoid unfairly assessing children who took time to become comfortable with the test or those who became fatigued. Unlike the rate data, the accuracy and consistency percentages that were used were the averages from all 5 times that a child performed the task. The results of the DDK task are found in Table 3 (HFA Group) and Table 4 (TD Group).

The data displayed in Tables 3 and 4 were entered into SPSS 19 (IBM, 2010), where a general linear model of repeated measures was used. Within-subjects effects, between-subjects effects, and pairwise comparisons were examined in the analysis.

RESULTS

Rate

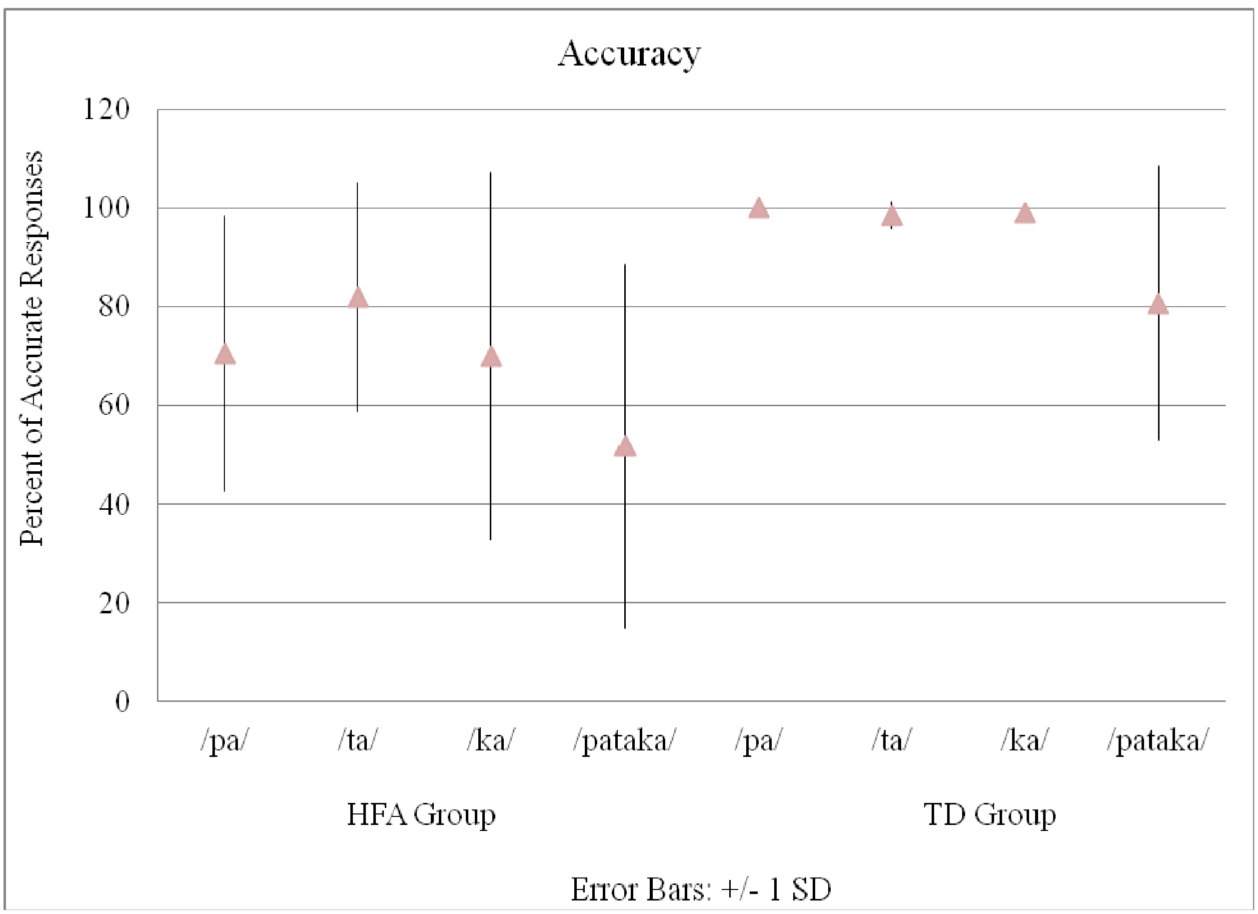
Figure 1.



The means and standard deviations for the rates of the HFA and TD groups for each of the DDK tasks are found in Table 5. In general, the HFA group (M = 4.033) tended to have faster rates across tasks than the TD group (M = 3.854), but these between-group rates were not found to be statistically significant in the Tests of Between-Subject Effects ($p = .784$, partial eta-squared = .007). However, the rate of the multisyllabic DDK task (/pataka/) was slower than the rates of the monosyllabic DDK tasks (/pa/, /ta/, and /ka/), regardless of group. This was also found to be statistical significanct on the Tests of Within-Subject Effects (p = .000, partial eta-squared = .819) and Pairwise Comparisons (Table 6). Figure 1 shows a full comparison of the means and standard deviations for the rates on all DDK tasks for both the HFA and TD groups. As described above, there is some overlap with the monosyllabic rates for both the HFA and TD groups, but the multisyllabic rate drops for both groups significantly. Also, although the TD group generally produced slower DDK repetitions, the standard deviations for this group were smaller than those for the HFA group.

Accuracy

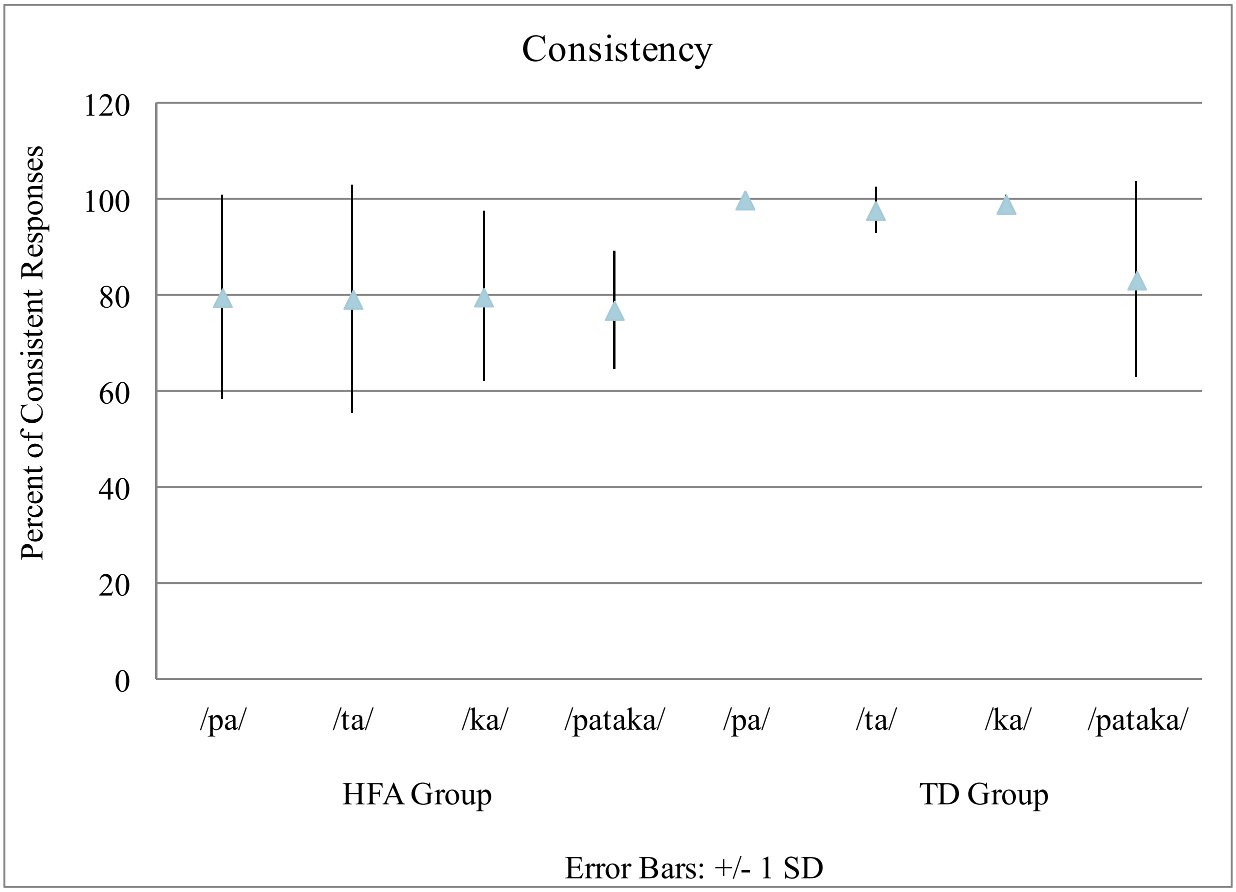
Figure 2.



The means and standard deviations for the accuracy percentages of the HFA and TD groups for each of the DDK tasks are found in Table 7. The TD group ($M = 94.591$) was significantly more accurate than the HFA group ($M = 68.533$) for all DDK tasks ($p = .013$, partial eta-squared = .413). However, the Tests of Within-Subject Effects were not found to be statistically significant ($p = 1.000$ for monosyllabic tasks, $p = .359, .168, .163$ compared to the multisyllabic task, partial eta-squared = .230). This means that accuracy was most likely determined by the group to which the subject belonged. Figure 2 shows the comparison of the means and standard deviations for the accuracy percentages on all DDK tasks for both the HFA and TD groups. The graph shows that the TD group had far higher accuracy scores than the HFA group. However, it also shows a much smaller standard deviation for the TD group in the monosyllabic tasks. Together, these observations could help provide further explanation for why the HFA group performed better on rate than the TD group.

Consistency

Figure 3.



The means and standard deviations for the consistency percentages of the HFA and TD groups for each of the DDK tasks are found in Table 8. Similarly to the results for accuracy percentages, the TD group (M = 95.031) was significantly more consistent than the HFA group (M = 78.880). Therefore, there was a statistical significance in the Tests of Between-Subjects Effects (p = .015, partial eta-squared = .398) and in the Pairwise Comparisons for Group (p = .015). However, this measure did not yield statistically significant scores in the Tests of Within-Subjects Effects (p = .173, partial eta-squared = .128), meaning that consistency was most likely not determined by the type of DDK task. Figure 3 shows the comparison of the means and standard deviations for the consistency percentages on all DDK tasks for both the HFA and TD groups. Although it has similar results to the accuracy scores, the multisyllabic standard deviations are much smaller.

Reliability

In order to determine if the coding was done accurately, a test of reliability was done on SPSS 19 with the data used in the current study versus those used in Richa Deshmukh's larger study. Rate, accuracy, and consistency scores were all found to be statistically significant. The variable of rate had the highest nonparametric correlation coefficient ($\rho = .906$; $p = .000$). However, accuracy ($\rho = .612$, $p = .000$, point-to-point agreement =71.4%) and consistency ($\rho = .476$, $p = .000$, point-to-point agreement = 69.6%) were found to be marginally acceptable in comparison with the larger data group, although not as reliable as the rate measurements.

DISCUSSION

The study presented above was used to compare the rate, accuracy, and consistency of children with high functioning autism with children that are typically developing on the motor speech task of diadochokinesis. Specifically, the two primary questions were: (1) Are there differences in performance on DDK tasks between typically-developing children and children with autism?, and (2) What are the differences in performance for monosyllabic sequences vs. trisyllabic sequences?

To answer the first question, the mean rate, accuracy, and consistency scores were compared between the two groups. For this sample, the HFA group generally had faster rates of utterances for the monosyllabic repetitions of /pa/ and /ta/, as well as for the multisyllabic repetition of /pataka/. However, the HFA group also had significantly lower accuracy and consistency scores than the TD group for all DDK tasks. The TD group also had much smaller standard deviations than the HFA group.

In regards to the second question about the differences in performance between the DDK tasks, participants from both groups produced much slower rates on the multisyllabic DDK task than on the monosyllabic tasks. Both groups also had lower accuracy scores on the multisyllabic task than on the monosyllabic tasks. However, there was no significant difference on the consistency between multisyllabic and monosyllabic tasks. The way that participants performed on the different kinds of DDK tasks were not affected by their group placement; rather they were only within-subject differences.

According to Shriberg et. al (2001), articulatory precision and prosody are two of the most distinguishable features between HFA children and typically developing children. With this in mind, the results from the current study only mildly support this evidence. While the children with HFA did have a lower performance than the TD children in terms of accuracy and consistency, their rates were significantly higher across the DDK tasks. Therefore, although this study demonstrated that this sample did have trouble with articulatory precision, their rate seemed to be unaffected.

There are many factors that may have contributed to this result. First, the sample sizes for both groups were small at only 7 participants each. There was also a significant age disparity between the two groups with the TD group being, on average, 6 months younger than the HFA group. In addition, participants from both groups tended to be within one standard deviation of the norm for the preliminary screenings and assessments of language and oromotor skills. Lastly, reliability scores for accuracy and consistency were only found to be marginally acceptable. In additional work on this project, steps would be taken to improve reliability.

However, if these factors were accounted for and the results remained the same, then this study may create a new platform for research in speech motor skills in children with HFA. If in fact children with HFA were to consistently produce faster DDK rates than TD children, then perhaps this could be a new indicator in the speech motor skills associated with autism. As a follow-up study, a researcher could look at other restricted repetitive behaviors (RRBs) typical of those with autism (Kogan et. al, 2009) and compare the rates of those actions to those of DDK tasks. RRBs include behaviors such as preoccupation with restricted patterns of interest, insistence to specific, nonfunctional routines, repetitive motor manners, and preoccupation with parts of objects instead of whole objects (Kim & Lord, 2010). Another follow-up study could be another DDK task using different consonant sounds, possibly those developed later in childhood. Since research on autism is still in its beginning stages, this study could lead to new breakthroughs on why so many children with autism have trouble communicating today.

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Table 1.

"Normative data on MRR in syllables/second for various syllables. Data for children are Fletcher's (1972) time-by-count values converted to count-by-time syllables. MRR data for adults are shown for comparison" (Kent, Kent, & Rosenbek, 1987).

	Syllable Pattern								
Age (years)	/pa/	/ta/	/ka/	/fa/	/la/	/pata/	/paka/	/taka/	/pataka/
6	4.2	4.1	3.6	3.6	3.8	2	1.9	1.9	1
7	4.7	4.1	3.8	3.7	3.8	2	1.9	1.9	1
8	4.8	4.6	4.2	4.1	4.4	2.4	2.1	2.1	1.2
9	5	4.9	4.4	4.4	4.4	2.5	2.3	3.3	1.3
10	5.4	5.3	4.6	4.8	4.8	2.7	2.3	2.3	1.4
11	5.6	5.6	5	5	5.3	3.1	2.6	2.6	1.5
12	5.9	5.7	5.1	5.4	5.4	3.2	2.6	2.7	1.6
14	6.1	6.1	5.4	5.6	5.7	3.6	2.9	2.9	1.8
Adults	6.0-7.0*	6.0-7.0*	5.5.-6.5*	6.4**	6.5**	4.6***			2.5***

*Approximate range of means from Figures 3,4, and 5. **From Sigurd (1973). ***From Tiffany (1980).

Table 2.

Ages, genders, and results of preliminary screenings and assessments for all participants in the current study.

HFA Group

Group Member	Subject Number	Age yrs:mos	Gender	SCQ	PPVT-IV	EVT	GFTA-2	OSMSE Stucture Function	OSMSE DDK
1	MSS 01	7:7	M	19	100	108	108	PASS	FAIL
2	MSS 02	10:3	M	11	123	93	96	PASS	FAIL
3	MSS 04	7:10	M	16	126	125	108	PASS	FAIL
4	MSS 08	5:1	M	18	88	86	116	PASS	FAIL
5	MSS 13	6:2	M	20	129	118	110	PASS	PASS
6	MSS 14	8:1	M	18	87	118	107	PASS	FAIL
7	MSS 21	6:6	M	14	103	89	40	PASS	FAIL
	Average	**7:4**		16.57	108	105.29	97.86		

TD Group

Group Member	Subject Number	Age yrs:mos	Gender	SCQ	PPVT-IV	EVT	GFTA-2	OSMSE Stucture Function	OSMSE DDK
1	MSS 12	6:2	M	4	95	113	110	PASS	FAIL
2	MSS 18	8:7	M	5	137	131	106	PASS	FAIL
3	MSS 20	4:2	F	2	123	113	109	N/A	N/A
4	MSS 24	9:7	M	1	120	132	106	PASS	FAIL
5	MSS 25	7:7	F	0	134	120	105	PASS	PASS
6	MSS 26	7:7	F	0	109	120	105	PASS	FAIL
7	MSS 27	4:5	F	6	103	100	117	N/A	N/A
	Average	**6:10**		2.57	117.29	118.43	108.29		

Table 3. Average rates, accuracy percentages, and consistency percentages for the HFA group.

HFA Group

		Rate (reps/sec)			
Group Member	Subject Number	/pa/	/ta/	/ka/	/pataka/
1	MSS01	4.44444	8	4.13044	1.21951
2	MSS02	8.92857	8.5	6.66667	2.38095
3	MSS04	6.11111	5.55556	4.81482	2.14286
4	MSS08	2.66667	2.66667	3.18182	1.33333
5	MSS13	4.73684	4.48276	3.75	1.09091
6	MSS14	4.84615	5.04854	3.97727	1.5625
7	MSS21	3.52941	2.93103	3.1579	1.06195
Means for all members		**5.0367**	**5.31208**	**4.23984**	**1.54172**

		Accuracy (%)			
Group Member	Subject Number	/pa/	/ta/	/ka/	/pataka/
1	MSS01	100	100	99.05	57
2	MSS02	100	100	100	100
3	MSS04	71.78	100	100	70.76
4	MSS08	35.83	90	49.29	10
5	MSS13	54.7	44.17	57.75	81.79
6	MSS14	38.73	55.01	83.6	43.09
7	MSS21	92.29	84.07	0	0
Means for all members		**70.4757**	**81.8929**	**69.9557**	**51.8057**

		Consistency (%)			
Group Member	Subject Number	/pa/	/ta/	/ka/	/pataka/
1	MSS01	100	100	80	61
2	MSS02	100	100	100	100
3	MSS04	71.78	100	100	70.76
4	MSS08	89.17	90	55.95	80
5	MSS13	54.7	44.17	57.75	78.45
6	MSS14	49.21	55.01	83.6	67.8
7	MSS21	92.3	65.67	80.76	80.56
Means for all members		**79.5943**	**79.2643**	**79.7229**	**76.9386**

Table 4. Average rates, accuracy percentages, and consistency percentages for the TD group.

TD Group

Group Member	Subject Number	**Rate** (reps/sec) /pa/	/ta/	/ka/	/pataka/
1	MSS12	4.61539	4.48276	4.48276	1.57895
2	MSS18	2.72	2.22222	2.34375	1.47059
3	MSS20	4.5	4.66667	4.375	1.15385
4	MSS24	6.42857	6.19048	5.625	1.73913
5	MSS25	5.41667	6.19048	6	1.66667
6	MSS26	5	4.375	4.73684	1.62791
7	MSS27	4.21053	4.54546	4.66667	0.88235
Means for all members		**4.69874**	**4.66758**	**4.60429**	**1.44563**

Group Member	Subject Number	**Accuracy** (%) /pa/	/ta/	/ka/	/pataka/
1	MSS12	100	100	100	100
2	MSS18	100	100	98	100
3	MSS20	100	97.14	100	100
4	MSS24	100	100	95.56	83.78
5	MSS25	100	100	100	95.56
6	MSS26	100	100	100	57.79
7	MSS27	100	92.73	100	28
Means for all members		**100**	**98.5529**	**99.08**	**80.7329**

Group Member	Subject Number	**Consistency** (%) /pa/	/ta/	/ka/	/pataka/
1	MSS12	100	100	100	100
2	MSS18	100	100	98	100
3	MSS20	100	97.14	100	100
4	MSS24	100	100	95.56	65.72
5	MSS25	100	100	100	95.56
6	MSS26	100	100	100	71.12
7	MSS27	100	87.27	100	50.5
Means for all members		**100**	**97.7729**	**99.08**	**83.2714**

Table 5.

The means and standard deviations for the rates of the HFA and TD groups.

Descriptive Statistics

	Group	Mean	Std. Deviation	N
MONO_PA	HFA	5.0376	2.02760	7
	TD	4.6987	1.14008	7
	Total	4.8682	1.59006	14
MONO_TA	HFA	5.3121	2.26833	7
	TD	4.6676	1.33871	7
	Total	4.9898	1.82037	14
MONO_KA	HFA	4.2398	1.21319	7
	TD	4.6043	1.16824	7
	Total	4.4221	1.15973	14
TRI_PATAKA	HFA	1.5417	.52389	7
	TD	1.4456	.31333	7
	Total	1.4937	.41770	14

Table 6.

Pairwise Comparisons for Rate Significance (/pa/, /ta/, /ka/, and /pataka).

Pairwise Comparisons

Measure:RATE

(I) DDK	(J) DDK	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-.122	.294	1.000	-1.048	.805
	3	.446	.188	.212	-.147	1.039
	4	3.374*	.360	.000	2.239	4.510
2	1	.122	.294	1.000	-.805	1.048
	3	.568	.283	.405	-.323	1.458
	4	3.496*	.452	.000	2.070	4.923
3	1	-.446	.188	.212	-1.039	.147
	2	-.568	.283	.405	-1.458	.323
	4	2.928*	.260	.000	2.110	3.747
4	1	-3.374*	.360	.000	-4.510	-2.239
	2	-3.496*	.452	.000	-4.923	-2.070
	3	-2.928*	.260	.000	-3.747	-2.110

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

*. The mean difference is significant at the .05 level.

Table 7.

The means and standard deviations for the accuracy of the HFA and TD groups.

Descriptive Statistics

	Group	Mean	Std. Deviation	N
MONO_PA	HFA	70.4757	27.92227	7
	TD	100.0000	.00000	7
	Total	85.2379	24.38286	14
MONO_TA	HFA	81.8929	23.09319	7
	TD	98.5529	2.78008	7
	Total	90.2229	18.01194	14
MONO_KA	HFA	69.9557	37.21070	7
	TD	99.0800	1.72186	7
	Total	84.5179	29.47540	14
TRI_PATAKA	HFA	51.8057	36.77750	7
	TD	80.7329	27.83860	7
	Total	66.2693	34.74540	14

Table 8.

The means and standard deviations for the consistency of the HFA and TD groups.

Descriptive Statistics

	Group	Mean	Std. Deviation	N
MONO_PA	HFA	79.5943	21.17353	7
	TD	100.0000	.00000	7
	Total	89.7971	17.86119	14
MONO_TA	HFA	79.2643	23.83921	7
	TD	97.7729	4.75239	7
	Total	88.5186	19.10366	14
MONO_KA	HFA	79.7229	17.73163	7
	TD	99.0800	1.72186	7
	Total	89.4014	15.72773	14
TRI_PATAKA	HFA	76.9386	12.46547	7
	TD	83.2714	20.49480	7
	Total	80.1050	16.62462	14